Lecture PT4

Risk Review of Established Explosives Operations

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INTRODUCTION

We have seen from the previous papers that considerable effort is put into the design, construction and operating control of an explosives operation. This operation could range from a major explosives chemical plant, a detonator assembly line, an explosives transport system through to a test firing facility. There are a large number of inputs to ensure that the operation in question is going to be safe to operate. These inputs include technical data, experience from previous operations (often incidents), accepted explosives good practice, industry guidelines and regulatory requirements. There will be company project management systems that will require some form of Hazard Study, perhaps with Risk Quantification. There will be detailed controls including operating instructions, emergency procedures, personnel training and plant maintenance requirements – all to ensure that the operation is safe.

Let us consider the life story of a typical operation

Prior to the operation being handed over to the personnel who will carry out the day to day activity, the hazard studies have been completed, the commissioning has been completed, the operating documents have been completed, the operators have been trained and the routine checks and inspections have been planned. The Basis of Safety (BOS) of the operation with respect to people and assets will be clearly defined. The period in the operation's life immediately after commissioning is a slightly tense one as it is a new operation, the people are new to the jobs and everyone involved is waiting for the final confirmation that "we got it right". During this period everyone is very alert to what is happening – listening for noises, looking for smoke/fumes and any signs that there is something not quite right. They are also religiously following the specified procedures and controls. It is not uncommon for minor defects to be identified during this period but it is rare for there to be a serious defect leading to an explosion. After a number of weeks we now have a safely operating facility and everyone feels more comfortable.

Everything is being done as it should be.

Good Explosives Practice is being followed.

The Basis of Safety is not compromised.

The operation is therefore confidently regarded as "safe"

Some time later there is an explosion. This could be one year — or many years later.

Someone says "But we have operated the same plant for thirty years and this is the first explosion! How can this be, nothing has changed?"

But something has changed; it is just that nobody noticed it (unless those involved right at the start many years ago missed something). The original Basis of Safety has been compromised and nobody was aware. It has been assumed up till now, perhaps based on audit and lack of incidents, that the operation is "safe". Clearly this was not the case. In the period between the plant being commissioned and the incident, a source of ignition has been generated and the operation has become unsafe.

In recent years I have had the opportunity to look at a number of incidents involving explosives. I have also had the opportunity to visit and inspect a large number of explosives facilities in many countries. All of the facilities involved have had safety management systems in place, some more comprehensive than others, yet in all cases failings, often serious, have been observed in attention to basic explosives safety controls. Examples of failings that have been observed include damaged to screens that are in place to avoid ingress of foreign bodies into mixers/cartridging machines, damaged earthing straps where static is a potential source of ignition, introduction of brass screws where copper presents a hazard, inappropriate repair of critical items of plant and so on. We are not talking here about major modifications to plant — what we are talking about is deterioration in explosive practices, that is to say that the initial "good practices" are no longer being consistently followed.

THE PROBLEM

The Basis of Safety is in the process of collapsing.

An incident is waiting to happen.

And no one is aware of it and existing management systems are not identifying the threat.

These failings, as often as not, are received as a complete surprise by local personnel. Suddenly they realise "Things have changed. How come we did not see them?" or more worryingly they may say "What, I didn't know that could happen! Nobody told me."

Many of the individual changes that have been observed have been very small and could easily be overlooked by a formal systems or operational audit and routine plant inspections. Many of these, in isolation, would not have a serious impact on safety but others would. However, when several of these apparently minor changes take place over a period of time in the same location or in the same operation then their cumulative effect can be to seriously undermine the original Basis of Safety for the operation. Consider, for example, the following scenario in a nitro-glycerine mixing building.

One element of the Basis of Safety will be controls to avoid the introduction of foreign bodies such as nails and screws, tools etc. These controls will include:

- no loose knives or tools in the raw materials handling areas
- all screws and nails in the RM store secured from falling out
- all RM transfer bins will have lids fitted at all times
- all RM's will be screened before leaving the building
- transfer bogies etc will have no loose parts that could contaminate the RM's
- all nuts and bolts in the mixer compartment will be locked/secured
- all non-metallic ingredients will pass through a metal detector prior to being screened
- all knives and loose articles will be secured by lanyards to ensure they cannot fall into the mixer
- all materials will be screened prior to charging the mixer

Over time each of these controls starts to deteriorate – perhaps due to a reduction in maintenance, personnel changes or change in operational focus - - - -. Normally a failure of one control would not have an immediate impact because the other systems would catch the "rogue" event. But if several of the controls have been weakened then there is a greater chance that the "rogue" will not be caught. Now we have an operation that we

would not consider safe. Eventually the situation gets to the point of total failure – a rogue event occurs, several of the key controls are failing - and an explosion results.

WHAT ACTION DID WE TAKE AS A RESULT OF THESE FINDINGS?

It was as a result of these findings that we first developed the "Explosives Basis of Safety (BOS) " package which identified for selected explosives technologies/operations the set of basic controls that ensured the safety of people, equipment and plant – these controls were called "Good Explosives Practice".

The highest order of the "Basis of Safety" in an operation where explosives materials are always present is the total avoidance of sources of ignition and as we are invariably dealing in this environment then we need to focus keenly on the control of sources of ignition followed by control of the consequences of ignition.

This BOS package has been used primarily as a training aid for plant/technical personnel but has more recently been developed into an explosives operation risk review process.

Basis of the Review Process.

In the context of this review an explosion is regarded as an uncontrolled chemical reaction that has the potential to cause injury and /or material damage to plant and process equipment. An explosion is therefore not limited to the detonation of an explosive substance such as lead azide. It will also include the reaction of materials which in combination can react violently or can contribute to the fire/explosion of other materials, for example the exothermic reaction/explosion of ammonium nitrate contaminated by sodium nitrite or the formation/explosion of an aluminium powder dust cloud.

Good Explosives Practice (GEP)

Explosives are regarded as hazardous materials but as long as their hazards are well recognised and understood, operations involving them can be conducted safely by the implementation of the appropriate controls such as formal hazard studies at an early project stage, operator training, instructions, appropriate materials of construction, protective barriers etc.

For an explosion to occur:

(a) an explosives material must be present

and

b) a source of ignition must be present.

It is Good Explosives Practice to:

(a) have explosives present only where they are intended to be and in the minimum quantities required for the operation,

(b) remove or as a minimum control the sources of ignition and

(c) minimise the consequences in the event that an ignition takes place.

Should an ignition take place then the consequences must be anticipated , understood and accepted. These consequences could include injury to personnel, damage to plant and equipment and business interruption. For example, in an operation involving local working, such as packaging of emulsion explosives , it is accepted that a mass explosion will result in loss of life, destruction of the building and business interruption. However, by controlling the potential sources of ignition, the risk of explosion is considered to be extremely low and therefore local operation is acceptable. In the case of lead azide pressing, the risk of explosion is much higher and the consequences are not considered

to be acceptable for local operation. The operation is therefore carried out remotely. In the event of an ignition and explosion there will be no personnel injuries and the quantity of material involved will not result in irreparable damage to the building and little if any business interruption.

The safety of an established explosives operation is very much about ensuring that GEP is followed at all times. The review that I will outline now focuses on how well the operation complies with the application of GEP to maintain the integrity of the BOS and hence its safety.

THE REVIEW PROCESS

The review is conducted by looking in detail at each operation that does or could involve an explosive, in most cases by direct observation of the activity and where this is not possible (e.g. the remote sieving of dry primary explosives) then by detailed discussion of the process and description of the operation. The following questions are asked:

- are there explosives present (or conditions that could give rise to an explosive material)?
- is there a potential fire/explosion hazard?
- what are the potential sources of ignition?
- how are those sources of ignition controlled?
- are those controls adequate?
- in the event of an ignition and propagation what would the consequences be?
- can these consequences be reduced?

The review is carried out by an experienced team (i.e. people who have the relevant experience in explosives) and each team includes personnel from the operation being studied. The review does not set out to audit the management system. Therefore, if plant management state that a particular control is in place e.g. a particular hazard is known and the appropriate procedure/system is in place and being implemented then this is accepted by the team but clearly if evidence points to a failure in that management system then this would be raised.

When a hazard is considered by the team to be inadequately understood and/or controlled then an appropriate action is recommended. In some cases the potential consequences for explosion will require further review and several options may be proposed that would require Business Management decision.

The team findings are recorded on a proforma (app 1 shows an example from the review of a detonator operation) that asks:

- What is the potential explosion hazard?
- What are the possible sources of ignition?
- What controls are in place and are they adequate?
- How many people are exposed directly and indirectly?
- Is there a business exposure?

There is also a proforma that helps the team to review the potential consequences of fire/explosion (app 2)

The team then has to make a qualitative assessment of the level of risk. In some cases the team may feel that a more detailed quantitative assessment is required in view of the potential consequences/risk profile.

This process has already been applied to two large explosives factories in ICI and in addition to pro-actively identifying potential exposures it also presented an excellent opportunity to train many of the site personnel in basic explosives safety concepts.

The primary output from the process is intended to be a review of the status of the implementation of “good explosives practice” and potential exposures to explosion at plant level. However, by carrying out this process we have also been able to identify a number of potential exposures including areas where corporate memory is starting to fail, poor communication between working groups and failure to adequately document safety design specifications. The BOS control documents in themselves are also very useful checklists when carrying out an explosion incident investigation

SUMMARY

The on-going safety of a well designed and commissioned explosives operation is critically dependent on clearly identifying it’s Basis of Safety and ensuring that throughout the lifetime of the plant that this Basis of Safety does not become compromised. Sadly we often only find out that the Basis of Safety has been compromised when we carry out a post accident technical investigation – despite having comprehensive management audit systems in place. By carrying out periodic safety risk assessments based on the application of Good Explosives Practice we can identify at an early stage when and where the BOS is likely to be compromised and take pro-active remedial action to maintain the BOS and so prevent an incident. Application of the technique will also aid management in identifying weaknesses developing in other key safety management systems. Such reviews could easily be incorporated as part of the safety management system and should be carried out by appropriately experienced and trained personnel.

PT4 – Appendix 1

Operational Risk Review Proforma

Plant area	Detonator department	Building no.	aaa	Licence Quantity	Y kg	Personnel Limits	x
Process	**Loading and Pressing detonators**						
Materials	**Lead Azide PETN**						
				Exposure		**Risk profile**	
Potential hazards	**Sources of Ignition**	**Controls**	**Direct persons**	**Indirect persons**	**Business**	**H/M/L**	**Actions**
Detonator Shaking **Explosion**	Friction and Impact	Soft materials of construction. Remote tipping and shaking. Tip into sawdust **(majority fall out but not all)**	1	- - - - -	- - - - -	M	**Both of these Operations are remote but in both cases the operator was observed having to complete both operations manually so defeating the purpose of having remote operation. Both operations have to be reviewed and equipment inspected**
Tipping into sawdust **Explosion**	Friction and impact	Materials of construction. Remote tipping. **(Imprecise location of the locking pin can cause some dets to miss drum)**	1	- - - - -	- - - - -	M	

PT4 – Appendix 2

Consequences of Ignition

Quantity of material involved	Number of people involved	Business exposure
Ask · Will all material be consumed? · Does all material have to be present? · Are other buildings/ operations likely to be affected? What are the alternatives for reducing inventory?	Ask · How many people are present? · Can the number exposed be reduced? · Are other people potentially exposed? Can operation be modified to reduce personnel exposure??	Ask · Will production be interrupted? · For how long? Are contingency plans necessary?


Risk Review of Established
Explosives Operations


Are you sure your plant is still
safe?

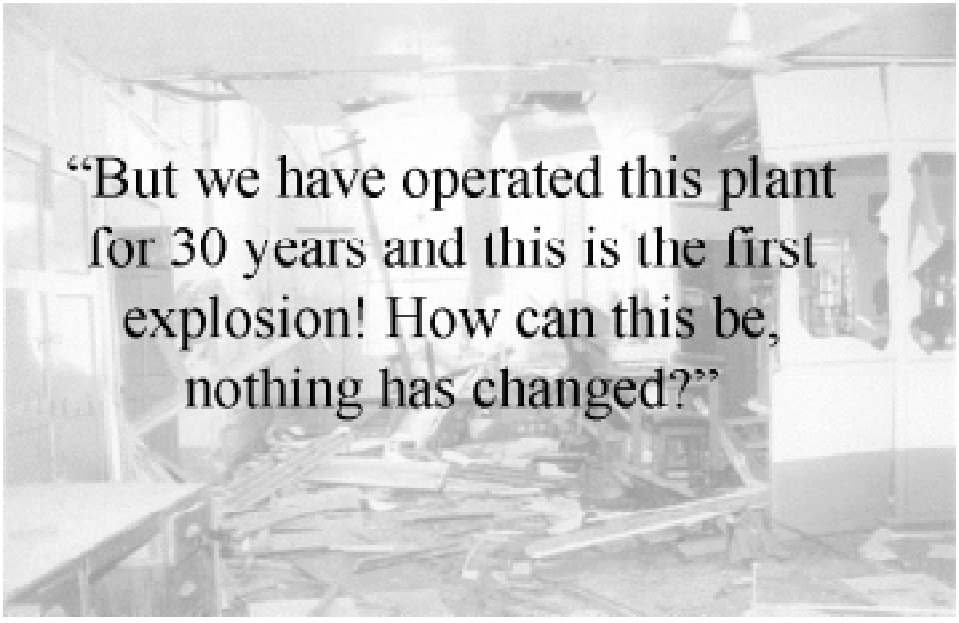
New Explosives Operation

- Designed and constructed for safety
- Embody Good Explosives Practice
- Input from incidents
- Clearly defined Basis of Safety
- Trained personnel
- Defined maintenance requirements
- Inspection/audit plan

Typical Operation History

- Design etc
- Commissioning
- Minor fault-finding
- Everybody happy!
- Operation now regarded as safe
- Settle into routine

Years later


"But we have operated this plant for 30 years and this is the first explosion! How can this be, nothing has changed?"

Something has changed!

- Nobody noticed
- Basis of Safety compromised
- Operation clearly not safe
- Is this an isolated event?

From Incident Investigations and plant visits

- Deterioration in basic explosives "good practice"
- Lack of awareness of basic safety elements by key personnel
- Management unaware of changes that have taken place

Examples of findings

- Damage to sieves
- Nuts/bolts not secured or missing
- Wrong materials of construction being used
- Earthing/grounding straps disconnected
- Cross-contamination of reactive materials
- Blast screens inadequate
- Loose metal items after metal detector
- Unauthorised tools
- Licence quantities not complied with
- Personnel unnecessarily exposed to effects of explosion

Basis of Safety is collapsing

An incident is waiting to happen

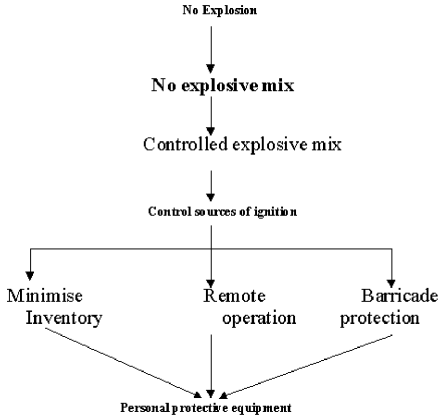
Typical reactions are:

- “When did that change take place?
- “How come we did not see that?”
- “What! I didn’t know that could happen!”
- “So we have just been lucky up till now?”

Explosives Basis of Safety Package

- Selected explosives technologies and activities
- Based on Explosives Good Practices
- Hazards
- Sources of ignition
- Controls

Basis of Safety



Basis of Safety for lead azide drying

1- Describe the detailed operation

- what gets done
- where is it done
- who does it
- how it is done
- how much material

2 - How can azide be initiated

- friction
- impact
- static
- flame
- spark
- shock

3 – For each define how they could arise and then specify how each will be controlled

friction

grit from surrounding area

- clean floor, footwear, wet mats, visitor control

foreign body in mix

- sieves and screens at earlier processing, covers on mix during transport, sealed wall joints, plugged nails/screws, authorised tool lists, no personal jewelry

hard surfaces

- soft materials of construction

careless movement by operators

- operating instructions, training, ergonomics

Good Explosives Practice key principles

- Explosives present only where needed
- Quantities minimised
- Remove or minimise the sources of ignition
- Minimise the consequences of ignition

App2

Good Explosives Practice

- fitting and maintenance of screens and sieves to prevent foreign objects entering mixers and pumps
- securing/control of loose articles e.g. tools, knives near open hoppers
- securing of nuts/bolts near open hoppers and mixers
- fitting, maintenance and checking of pump safety devices
- compliance with licence
- minimise inventory
- waste segregation and labelling
- raw material segregation to avoid cross-contamination
- knowledgeable employees

Safety Assessment

- Uncontrolled chemical reactions
- Control sources of ignition
- Manage the consequences of ignition

The Assessment Process

- Detailed observation of the activity
- Are there explosives materials present?
- Is there a fire/explosion hazard?
- What are sources of ignition?
- How are they controlled?
- Are the controls adequate?
- What would be consequences?
- Can consequences be reduced?

To conduct a review

- Establish Basis of Safety and Good Practices
- Experienced personnel
- Awareness training

Record findings

- What is the hazard?
- What are sources of ignition?
- Controls/adequacy
- How many people exposed?
- What business exposure?
- Perceived risk profile
- Actions

Plant area		Building No		Licence quantity		Personnel limits	
Process							
Materials							
Potential hazards	Sources of ignition	Controls	dir person	Exposure indir person	business	Risk profile H/M/L	Actions

Study leader Date App3

Plant area Detonators	Building No	Licence quantity 34kg	Personnel limits 14 + 2
Process	Detonator loading and pressing		
Materials	Lead Azide, PETN		

Potential hazards	Sources of ignition	Controls	dir person	Exposure indir person	business	Risk profile H/M/L	Actions
Detonator shaking Explosion	Friction & impact	Soft materials of construction Remote tipping/shaking. Tip into sawdust.Most fall out but not all	1	---	- - -	M	Both of these operations are remote but in both cases the operator was observed having to complete both operations manually so defeating the intent of having remote operation both operations need to be reviewed and equipment inspected.
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Study leader Date App3

App 4

	Consequences of ignition	
Quantity of material involved	**Number of people involved**	**Business exposure**
Ask ❖ Will all material be consumed? ❖ Does all material have to be present? ❖ Are there other buildings likely to be affected? What are better alternatives?	Ask ❖ How many people are required to be present? ❖ Can the number be reduced? ❖ Are other people potentially exposed? What are better alternatives?	Ask ❖ Will production be interrupted? ❖ For how long? Are contingency plans required?

Summary

- Clearly identify Basis of Safety
- Periodic assessment of BOS against GEP
- Requirement for experience
- Incorporate assessment in safety management system

- "When did that change take place?
- "How come we did not see that?"
- "What! I didn't know that could happen!"
- "So we have just been lucky up till now?"